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Phytoplankton Studies Within the Virginia Barrier Islands I. Seasonal Study of Phytoplankton in Goose Lake, Parramore Island

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Abstract—The phytoplankton of Goose Lake, an oligohaline lake on Parramore Island, was studied for one year. The populations consisted primarily of ultraplankton and nanoplankton sized forms with diatoms and chlorophyceans dominant most of the year. A general pattern of seasonally higher cell concentrations in early summer and fall was noted, with an unidentified ultraplankton sized component prominent throughout the collection period. A list of 154 species is given.

Introduction

Parramore Island is located on the eastern shore of the Delmarva Peninsula in Accomack County, Virginia. It is part of the barrier island complex under the management of The Nature Conservancy and is located approximately 50 km northeast of the Chesapeake Bay entrance (37° 32′ N. Lat., 75° 37′ W. Long.). Parramore Island is approximately 13.3 by 3 km in size, with its long axis in a general northeast direction. The Island's eastern shoreline is bordered by a parallel series of relict dunes that extend to the island's interior, with elevations up to seven m and a well-developed floral cover. The island topography decreases in elevation along the southern and western margin where the vegetation blends into an extensive salt marsh. Goose Lake has formed between two of these relict dune lines, is finger-shaped and up to 1.5 m in depth, with an area of approximately 0.07km^2. The size varies with seasonal periods of heavy rain, and the occasional inundation of seawater through the southern end. To the south an earlier channel to Swash Bay and the numerous tidal guts of the bordering marsh have been blocked due to vegetational growth and the accumulation of autochthonous material. During flood periods from storm tides, saltwater entry may occur at this end of Goose Lake. The lake substrate consists of a mixture of silt, sand, detrital material, and various inorganic substances. It is black in color, soft in texture, and its anaerobic state is indicated by the hydrogen sulfide odor common to the bottom samples. More detrital material is found along the shoreline, where a variety of marginal wetland plants are established. A common submergent is *Ruppia maritima*.

Several previous phytoplankton studies have been conducted in the general area of the Barrier Islands. Nearshore phytoplankton, in the vicinity of Assateague Island, was studied by Marshall and Bowker (1976) regarding the composition and concentration of cells in relation to chlorophyll values. Their samples were dominated by several species of diatoms and the dinoflagellate *Ceratium tripos*, with the diatoms representing 55% of the composition at the station nearest Assateague Island. In a seasonal study of the phytoplankton within the channels of the Barrier Island complex, Marshall, Nesius and Cibik (1980) found *Skeletonema costatum* the dominant species throughout the year. They noted the most common species in these channels were similar to the dominant phytoplankters in the continental shelf waters. A list of summer chlorophyceans and cyanophyceans from Accomack and Northampton Counties was made by Nemeth (1969), but none of his stations were on any of the Barrier Islands. His study emphasized fresh water sites and he recorded 102 chlorophyceans, 43 cyanophyceans, and 15 other species.

Methods

Goose Lake is centrally divided into a northern and southern half by an earthen mound constructed for the placement of a road across the island. Free flow between the 2 halves of the lake takes place through a culvert approximately 0.3 m in diameter placed at basin level. During each of the eight collection trips between October 1978 and October 1979, samples were taken from two stations located in each half of the lake. These surface water samples (500 ml) were preserved immediately with a buffered formalin solution. A settling and siphoning procedure was followed to obtain a 20-ml concentrate which was subsequently examined in a settling chamber with a Zeiss Inverted Plankton Microscope. Salinity readings were taken with a portable Beckman salinometer. The classification used in this report is based mainly on the revisions by Hendey (1974) and Parke and Dixon (1976).

Results and Discussion

Goose Lake is considered an oligohaline lake with generally low saline values ($< 5^0/_{00}$). Readings throughout the lake for the collection period indicated rather consistent salinities between 2 and $3^0/_{00}$. Occasionally, storm tide entry will occur from the southern end of

Goose Lake. Such an event was noted by Dr. James Matta of Old Dominion University on 25 October 1978. He took salinity readings at that time that indicated average values of $20^0/_{00}$ in both the southern and northern sections of the lake. By 26 January 1979 the average salinity value for the entire lake had decreased to $2.5^0/_{00}$, where it remained at approximately that level into October 1980, with only slight variations between both sections.

A total of 154 phytoplankters was identified within the samples. The breakdown of species for the various taxonomic groups was as follows: Bacillariophyceae (61), Euglenophyceae (22), Cyanophyceae (18), Dinophyceae (8), Chlorophyceae (21), Cryptophyceae (2), Xanthophyceae (5), Haptophyceae (2), Prasinophyceae (2), Rhodophyceae (1), and one vascular plant *Lemna minor*. The phytoplankton community was dominated throughout the year by various diatoms and chlorophyceans, with various cyanophyceans prominent (see Table 1). Seasonally there were early summer and fall maxima of numbers, with later summer and winter minima. Lowest concentrations occurred during winter (Figure 1).

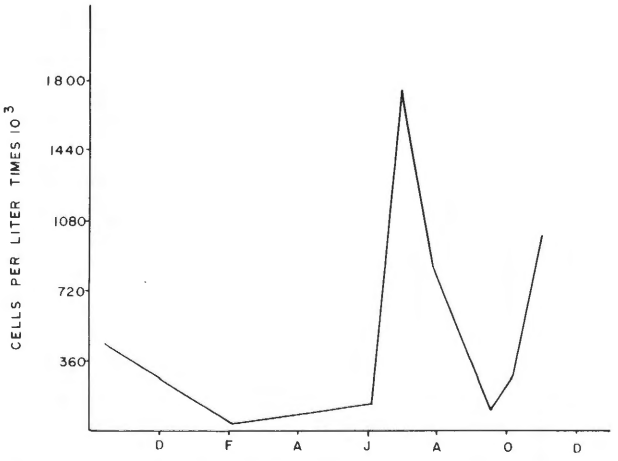

FIG. 1—Average seasonal concentrations of phytoplankton in Goose Lake from October 1978 through October 1979.

The winter phytoplankton possessed two diverse size groups of diatoms. The large cells of *Surirella striatula* and *Tropidoneis lepidoptera* were very common in all the samples with the more abundant smaller diatoms, such as *Navicula salinarum, Amphora coffeaeiformis, Navicula* sp., *Navicula maculata,* and *Nitzschia vermicularis. Nannochloris atomus* was also dominant with several cyanophyceans *(Anacystis marina, A. dimidiata, Oscillatoria submembranaceae),* and the chlorophycean, *Chlorella vulgaris,* common in all samples. Lowest concentrations for the collection period were noted on 2 February 1979 when average cell counts were 67,240 cells/l. One of the dominant species during this period was unidentified, but under light microscopy resembled oocystaceans previously described in the literature (Bourrelly, 1966; Simpson and Van Valkenburg, 1978). This species was round, 4-5u in size, occurring often in groups of four, with what appeared as a "rough" and thickened outer wall.

The spring samples and the early summer bloom consisted mainly of several Pennales diatoms that were less than 30 um in length and several small Centrales forms. *Navicula* sp., *Navicula arvensis, Epithemia argus, Stauroneis anceps* and *Nitzschia amphibia* were found in high concentrations. *Cyclotella meneghiniana* and *C. caspia* were also prominent. Other conspicuous species included *Euglena ehrenbergii, Nannochloris atomus,* and *Kirchneriella lunaris.* High concentrations of green round to irregularly shaped forms, 1.2 to 2.5 μm in size, were in all the spring samples, plus an unidentified Centrales diatom with an average diameter of 3.6 μm. The unidentified 1.5 to 2.5 sized "cells" were not included in the cell counts, but easily would have surpassed the other taxa in number. The early summer bloom continued into July with nanoplankton diatoms still dominant. However, the dominant phytoplankton assemblage was diverse in composition. *Chaetoceros debilis, Surirella striatula, Cyclotella striata, Navicula arvensis, Rhabdonema minutum,* and the unknown Centrales *(Cylindropyxis profunda ?)* were abundant. Phytoflagellates included *Trachelomonas hispida, T. volvocina* var. *puncta, Gymnodinium danicans,* and *Phacus longicauda.* There were high concentrations of *Anacystis marina, A. montana minor,* and *A. thermalis.* An unidentified *Scenedesmus* sp. was also abundant with *Nannochloris atomus, Tetraedrom muticum,* and *Kirchneriella lunaris.* The highest concentrations of the study occurred at this time with 1.78 million cells/l recorded on 27 June 1978. During this period there were large concentrations of *Enteromorpha intestinales* common in the benthos in both sections of the lake. The broken fronds of this alga were floating at the surface and part of the phytoplankton community.

The phytoplankton in late summer was dominated by an early bloom of *Cyclotella striata* and *Cyclotella caspia,* with *C. caspia* retaining high concentrations into fall. A mixture of these and other small sized diatoms ($<$ 30 µm) and blue green algae *(Anacystis montana, Nostoc commune, Oscillatoria submembranacea)* dominated the late summer flora. Several *Oedogonium* species were present, with *Lemna minor* (common duckweed) found in high concentrations at the surface in the southern section of Goose Lake. The lowest concentrations for summer were noted in late September with *Cyclotella caspia, C. striata,* and *Nitzschia communis* var. *hyalina* the dominant species.

The early fall period was accompanied by a sharp rise in the nanoplankters, with chlorophyceans, diatoms, and phytoflagellates abundant. The diatoms consisted of mainly *Rhabdonema minutum, Nitzschia closterium, Cocconeis pendiculus, Nitzschia* sp., and *Cyclotella* spp.. The major flagellates were *Chrysococcus minuta,* and *Cryptomonas* spp., with the green algae *Nannochloris atomus, Chlorella ellipsoidea* and *Chlorella vulgaris* also numerous. Of interest was the

presence of several *Euglena* species, mainly composed of *Euglena agilis, Euglena pumila,* and *Euglena ehrenbergii.* In addition, *Phacus* sp. #1 was also common. This seasonal bloom was distinct but smaller in magnitude in comparison to the early summer bloom.

The productivity pattern resulting from phytoplankton growth for the period of study was peak development during early summer (where average counts reached 1.7 million cells per liter on 29 June 1979). A marked reduction followed with a second surge of growth in fall reaching 0.9 million cells per liter on 29 October 1979 (Table 2). The pattern from fall 1978 was a gradual decline into winter, where lowest values occurred in February (67,240 cells/l).

Table 2.
Average cell counts for phytoplankton at stations in the southern and northern sections of Goose Lake during the collection period. Numbers represent cells/liter.

Date	South Section	North Section	Average
13 Oct 78	364,520	539,480	452,000
2 Feb 79	46,600	87,880	67,240
3 Jun 79	174,850	135,330	155,090
29 Jun 79	1,788,800	1,682,400	1,735,600
27 Jul 79	506,480	981,920	744,200
17 Sep 79	142,640	160,280	151,460
1 Oct 79	210,080	432,640	321,360
29 Oct 79	1,029,660	773,760	901,710

The nanoplankton composition has been generally defined by Strickland (1960) as having a size range of 10 to 50 µm, with those forms having sizes between 0.5 to 10 µm as belonging to the ultraplankton. Using this classification, the major phytoplankton components in Goose Lake were the ultraplankton with another major group consisting of nanoplankters in the 10- to 20-µm size category. The more abundant ultraplankton were the diatoms *Cyclotella caspia, Navicula atomus,* and an unknown Centrales diatom; the cyanophyceans *Anacystis marina, A. montana minor, A. thermalis;* the chlorophyceans *Chlorella vulgaris* and *Nannochloris atomus;* the chrysophyceans *Chrysococcus minutus, Ochromonas variabilis, O. miniscula;* the euglenophycean *Trachelomonas volvocina* var. *puncta;* and the xanthophycean *Monodus guttula.* Still not fully addressed are unidentified ultraplankton less than 2.5 µm in size, that were common throughout the year. Further study of this component of the plankton community is needed to more fully ascertain their role in productivity and contribution to various lentic food chains. The dominant nanoplankton were *Cyclotella* spp., and a variety of Pennales forms. Of note were *Rhabdonema minutum, Amphora coffeaeiformis, Cocconeis* sp., and *Nitzschia closterium.* The nanoplankton phytoflagellates were represented by *Cryptomonas* spp., *Trachelomonas* spp., and *Nephrochloris salina.*

The seasonal populations at Goose Lake represented combinations of what are considered typical marine and fresh water species throughout the year, with fewer of the more common fresh water species found in winter. These results differ from composition studies made in the channels of the Barrier Islands and the coastal waters where marine diatoms dominated (Marshall, et al., 1980; Marshall and Bowker, 1976). However, the unidentified ultraplankton component noted in Goose Lake was similar to what Marshall, et al. (1980) reported within the Barrier Island channels. Different population assemblages were also present within the chlorophycean, cyanophycean, and euglenophycean groups in Goose Lake in comparison to those noted on the nearby mainland by Nemeth (1969).

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Table 1. Phytoplankton identified in Goose Lake. Seasonal presence is noted with X; the more dominant species are indicated by A, B, C, with A being most abundant.

	W	S	S	F
Bacillariophyceae				
Amphora sp.	-	X	-	-
Amphora coffeaeiformis Kutzing	A	X	-	X
Amphora ovalis (Kutzing) Kutzing	-	-	-	X
Auricula insecta (Grunow) Cleve	X	-	-	X
Caloneis westii (Smith) Hendey	-	-	-	X
Chaetoceros sp.	-	-	X	X
Chaetoceros compressus Lauder	-	-	X	X
Chaetoceros debilis Cleve	-	-	B	-
Cocconeis sp.	-	-	X	X
Cocconeis pediculus Ehrenberg	-	-	-	B
Coscinodiscus sp.	-	-	-	X
Cyclotella sp.	-	X	X	C
Cyclotella caspia Grunow	-	C	A	A
Cyclotella meneghiniana Kutzing	-	C	X	X
Cyclotella striata (Kutzing) Grunow	-	-	A	B
Cymbella sp.	-	-	-	X
Cymbella ventricosa Agardh	-	-	X	X
Epithemia argus (Ehrenberg) Kutzing	-	B	X	-
Eunotia praerupta Ehrenberg	-	X	-	-
Fragilaria sp.	-	X	-	-
Fragilaria capucina Desmazieres	-	-	X	X
Fragilaria curvata Skvortzow	-	-	-	X
Fragilaria oceanica Cleve	X	-	-	X
Fragilariopsis cylindrus (Grunow) Helmcke et Krieger	-	X	X	-
Grammatophora marina (Lyngbye) Kutzing	-	-	-	X
Gyrosigma baltieum (Ehrenberg) Cleve	-	X	X	X
Licmophora sp.	-	X	-	-
Licmophora paradoxa (Lyngbye) Agardh	X	-	-	-
Melosira granulata (Ehrenberg) Ralfs	-	X	-	-
Melosira granulata angustissima Muller	-	-	-	X
Navicula sp.	C	C	-	X
Navicula amphipleuroides Hustedt	-	-	-	X
Navicula arvensis Hustedt	X	B	B	-
Navicula atomus (Kutzing) Grunow	-	X	X	-
Navicula hennedyi W. Smith	-	X	-	-
Navicula humerosa Brebisson	-	X	-	-
Navicula irrorata Greville	X	-	X	-
Navicula lanceolata var. *phyllepta* (Kutzing) Cleve	-	-	-	X
Navicula maculata (Bailey) Cleve	C	-	-	X
Navicula rhombica Gregory	-	X	-	X
Navicula salinarum Grunow	A	-	X	X

Table 1. (continued)

	W	S	S	F
Nitzschia sp.	-	X	-	-
Nitzschia amphibia Grunow	-	X	X	X
Nitzschia clausii Hantzsch	X	C	X	X
Nitzschia closterium (Ehrenberg) W. Smith	X	X	X	B
Nitzschia communis var. *hyalina* Lund	-	-	C	X
Nitzschia longissima (Brebisson) Ralfs	-	X	-	X
Nitzschia paradoxa (Gmelin) Grun	-	-	X	X
Nitzschia proxima Hustedt	-	-	-	X
Nitzschia sigmaformis Hustedt	-	-	-	X
Nitzschia vermicularis (Kutzing) Hantzsch	C	X	X	X
Pinnularia sp.	-	-	X	X
Pinnularia major (Kutzing) Rabenhorst	-	-	-	X
Pinnularia rectangulata (Gregory) Cleve	-	-	-	X
Plagiogramma staurophorum (Gregory) Heiberg	-	-	-	X
Rhabdonema minutum Kutzing	-	-	C	B
Stauroneis anceps var. *hyalina* Peragallo	-	B	X	-
Surirella fastuosa Ehrenberg	X	-	-	-
Surirella striatula Turpin	B	X	C	X
Tropidoneis lepidoptera (Gregory) Cleve	B	-	X	X
Unknown Centrales species	-	-	A	-
Chlorophyceae				
Ankistrodesmus falcatus (Corda) Ralfs	-	-	-	X
Ankistrodesmus falcatus var. *acicularis* (A. Braun) G. S. West	-	-	-	X
Chlamydomonas sp.	-	X	X	X
Chlorella sp.	-	X	X	-
Chlorella ellipsoidea Gerneck	-	-	X	C
Chlorella vulgaris Beyerinck	C	-	X	C
Kirchneriella lunaris (Kirchner) Mobius	-	B	C	-
Nannochloris atomus Butcher	B	A	A	B
Oedogonium sp. #1	-	-	-	X
Oedogonium sp. #2	-	X	X	X
Oedogonium sp. #3	-	X	X	-
Oedogonium pungens Hirn	-	-	X	-
Oocystis sp.	-	X	X	X
Scenedesmus sp. #1	-	-	-	X
Scenedesmus sp. #2	-	-	B	-
Scenedesmus bijuga (Turpin) Lagerheim	-	-	X	X
Scenedesmus quadricauda (Turpin) Brebisson	-	-	X	-
Staurastrum sp.	-	-	X	-
Tetraedron sp.	-	-	-	X
Tetraedron muticum (A. Braun) Hansgirg	-	-	C	-
Unidentified Oocystacean	C	-	-	-
Prasinophyceae				
Pyramimonas micron Conrad and Kufferath	-	-	-	X
Tetraselmis maculata Butcher	-	-	-	X
Cryptophyceae				
Chroomonas amphioxeia (Conrad) Butcher	-	X	X	-
Chroomonas salina (Wislouch) Butcher	-	-	-	X
Cryptomonas sp.	-	-	-	X
Cryptomonas irregularis Butcher	-	-	-	C
Cryptomonas rostrella Lucas	-	-	-	C
Plagioselmis sp.	-	-	-	X
Chrysophyceae				
Calycomonas ovalis Wulff	-	-	-	X
Calycomonas wulfii Conrad et Kuff.	X	-	-	-
Chromulina parvula Conrad	-	-	-	X
Chrysococcus minutus (Fritsch) Nygaard	-	-	-	B
Mallomonas sp.	-	-	-	X
Ochromonas miniscula Conrad	-	-	-	X
Ochromonas variabilis H. Meyer	-	-	B	-
Xanthophyceae				
Monodus guttula Pascher	X	-	-	X
Nephrochloris salina Pascher	-	-	-	X
Tribonema affine G. S. West	-	X	X	X
Tribonema minus (Willie) Hazen	-	-	X	X
Tribonema monochloron Pascher et Geitler	-	X	X	-
Haptophyceae				
Chrysochromulina minor Parke et Manton	-	-	-	X
Pavlova salina (Carter) Green	-	-	X	X
Euglenophyceae				
Euglena sp.	-	-	X	X
Euglena acus Ehrenberg	-	-	X	X
Euglena agilis Carter	-	-	X	C
Euglena deses Ehrenberg	-	-	-	X
Euglena ehrenbergii Klebs	-	C	X	C
Euglena fusca (Klebs) Lemmermann	-	-	-	X
Euglena mutabilis var. *mainxi* Gojdics	-	-	X	-
Euglena proxima Dangeard	-	-	X	X
Euglena pumila Campbell	-	-	-	C
Eutreptia lanowii Stever	-	-	-	X
Eutreptia viridis Perty	X	-	-	-
Phacus sp. #1	-	-	-	C
Phacus sp. #2	X	-	-	-
Phacus curvicauda Swirenko	-	-	-	X
Phacus lemmermanni (Swirenko) Skvortzow	-	-	X	-
Phacus longicauda (Ehrenberg) DuJardin	-	-	C	X
Trachelomonas sp.	-	-	X	X
Trachelomonas acanthostoma (Stokes) Deflandre	-	-	-	X
Trachelomonas charkowiensis Swirenko	-	-	-	X
Trachelomonas hispida (Perty) Stein	X	C	B	X
Trachelomonas hispida var. *punctata* Lemmermann	X	-	-	X
Trachelomonas volvocina var. *punctata* Playfair	-	-	C	-
Cyanophyceae				
Agmenellum quadruplicatum (Meneghini) Brebisson	-	-	-	X
Anabaena sp.	-	-	X	-
Anacystis aeruginosa Drouet et Daily	-	-	X	-
Anacystis dimidiata (Kutzing) Drouet et Daily	C	X	-	X
Anacystis marina (Hansgirg) Drouet et Daily	C	-	C	X
Anacystis montana minor (Wille) Drouet et Daily	-	-	C	X
Anacystis thermalis (Meneghini) Drouet et Daily	-	-	C	X
Calothrix parietina Thuret	-	-	X	-
Gomphosphaeria aponina Kutzing	-	-	X	-
Johannesbaptistia pellucida (Dickie) Taylor et Drouet	X	X	X	X
Microcoleus lyngbyaceus (Kutzing) Crouan	-	-	-	X
Nostoc commune Vaucher	-	-	C	X
Oscillatoria sp.	-	X	-	-
Oscillatoria lutea Agardh	-	X	-	-
Oscillatoria submembranaceae Ardissone et Strafforella	C	X	C	X
Schizothrix arenaria (Berkeley) Gomont	-	-	X	X
Schizothrix calcicola (Agardh) Gomont	-	-	-	X
Spirulina subsalsa Oersted	-	X	X	X
Dinophyceae				
Goniaulax diacantha (Meunier) Schiller	-	-	-	X
Gymnodinium sp. #1	-	-	-	X
Gymnodinium sp. #2	X	X	X	X
Gymnodinium danicans Campbell	-	C	C	X
Gyrodinium estuariale Hulburt	-	X	X	-
Protoperidinium sp.	-	-	-	X
Protoperidinium achromaticum (Levander) Balech	-	-	X	X
Protoperidinium pentagonum (Gran) Balech	-	-	X	X
Others				
Campeopogan coeruleus Balbis	-	-	-	X
Lemna minor L.	-	-	X	X
Unidentified ultraplankton	X	B	B	X

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